Physical and Optical Structures in the Upper Ocean of the East (Japan) Sea

Craig M. Lee
University of Washington
Applied Physics Laboratory
1013 NE 40th St.
Seattle, WA 98105-6698
(206)685-7656
(206)543-6785 (fax)
craig@apl.washington.edu

Kenneth H. Brink
Department of Physical Oceanography, MS-10
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(508)289-2535
(508)457-2181 (fax)
kbrink@whoi.edu

Burton H. Jones
Department of Biological Sciences
University of Southern California
Allan Hancock Foundation Building 107
Los Angeles, CA 90089-0371
(213)740-5765
(213)740-8801 (fax)
bjones@usc.edu

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LONG-TERM GOALS

This study fits within our broader scientific efforts to understand:

- Physical and biological responses of the upper ocean to atmospheric forcing and how these penetrate to the interior.
- The dynamics and biological influences of instabilities, secondary circulations and vertical motions associated with upper ocean fronts.
- Physical and bio-optical transitions between coastal and central basin waters.

OBJECTIVES

We seek to understand the processes that control physical and bio-optical variability in the upper ocean of the East/Japan Sea. Specifically, we are interested in:

- The upper ocean response to strong wintertime forcing (Siberian cold air outbreaks) at the subpolar front.

- The resulting formation, subduction, and spreading of intermediate waters.
- The dynamics of the subpolar front.
- Contrasting seasonal and coastal/central basin bio-optical variability.

APPROACH

Two cruises, one of which took place in May 1999 and a second that will occur in January 2000, sample upper ocean and atmospheric boundary layer (Dr. C. Dorman, SIO) variability in the Japan/East Sea. The spring cruise focused on frontal dynamics, characterizing bio-optical variability associated with the spring phytoplankton bloom and documenting the location, range and properties of water masses formed at the subpolar front during the preceding winter. The wintertime cruise will focus on documenting the upper ocean response to cold air outbreaks with particular attention to processes associated with water mass formation and subduction at the subpolar front. Both cruises employ a towed, undulating profiler (SeaSoar) to make highly-resolved observations of the upper ocean. We use real-time remotely sensed sea surface temperature and ocean color images (R. Arnone, NRL and scientists from the Korean Ocean Research and Development Institute, KORDI) to determine the location of the subpolar front and to select intensive survey locations. Real-time access to remotely sensed imagery allows us to modify our sampling in response to changes in the front. Repeated intensive grid surveys provide approximately synoptic, three-dimensional coverage while a sequence of longer sections document oceanic and atmospheric boundary layer variability away from the front. In addition to the suite of physical and bio-optical sensors carried by SeaSoar, we employ a shipboard Acoustic Doppler Current Profiler (ADCP) and GPS navigation to measure upper ocean currents. Sampling includes a limited number of hydrographic stations and optical profiles off the Korean coast and across the subpolar front. Professor S. Yang (Kwangju University) is responsible for additional biological and bio-optical sampling (e.g. nutrient analysis, pigments). Dr. M. Suk (KORDI) and colleagues are providing additional support.

WORK COMPLETED

The first of two Japan/East Sea SeaSoar cruises took place between 19 May and 3 June, 1999 aboard the R/V Roger Revelle. The field program involved scientists from the United States, Korea and Russia and included specialists in physical oceanography, biological oceanography, bio-optics, boundary layer meteorology and remote sensing. Real-time, remotely-sensed sea surface temperature imagery guided us to a southward meander of the subpolar front located directly over the Yamato Rise (Figure 1). SeaSoar sampling included a long section extending across the western half of the basin, two intensive, quasi-synoptic surveys of the subpolar front, a coarse survey of a prominent meander feature south of the frontal region and a section across the Korean shelf near Pohang. Our measurement program combined surveys dedicated to resolving the three-dimensional structure of the subpolar front with longer north-south sections designed to explore the southward spreading of watermasses formed at the front during the previous winter. Shipboard sensors made continuous measurements of meteorological variability while atmospheric soundings were carried out each day to obtain vertical profiles of temperature, humidity, pressure and winds. Underway measurements of absorption, scattering, attenuation and remote sensing reflectance were also collected (Dr. R. Gould, NRL).

RESULTS

SeaSoar sections across the subpolar front (Figure 2) reveal near-surface temperature contrasts as strong as 5 °C over 10 km, with the strongest part of the front concentrated in the upper 200 m. Upper

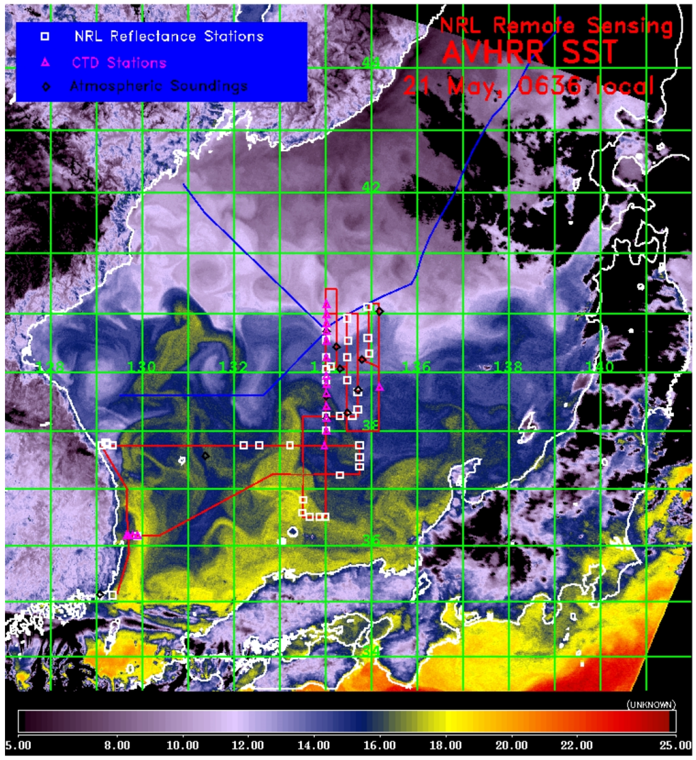

Figure 1. AVHRR sea surface temperature image from 21 May 1999. The red line marks the SeaSoar survey track, while the various symbols indicate the location of other sampling stations.

ocean stratification varies markedly across the front. South of the interface, a 30 m deep weakly stratified surface layer rests on top of a sharp seasonal pycnocline. Beneath the seasonal pycnocline, a more weakly stratified permanent pycnocline extends to 250 m. Stratified waters extend to near the surface on the northern side of the front, with a weaker, shallower seasonal pycnocline and only weak stratification below. Southern waters are warmer and more saline than those to the north. South of the front, a chlorophyll fluorescence maximum hugs the top of the seasonal pycnocline, while elevated levels of chlorophyll fluorescence extend closer to the surface to the north. Dissolved oxygen measurements are still undergoing post-cruise calibration. Comparisons with bottle oxygen measurements made along the same line three days later indicate that elevated levels of dissolved oxygen follow the region near the 27 kg/m^3 isopycnal as it slips beneath the seasonal pycnocline south of the front. However, the high values of dissolved oxygen seen in Figure 2 beneath the seasonal pycnocline are clearly bogus. We are currently working to understand the sensor's response and to develop a correction for these measurements. A weak signal of elevated chlorophyll fluorescence and low transmissivity extends downward in a finger along the frontal interface. Careful inspection reveals that these waters are also slightly fresher their surroundings, with salinities similar to those found in surface waters to the north of the front. The combination of oxygen, fluorescence, light transmission and salinity signals suggests that these waters have recently been near the surface, perhaps forming in winter or spring and spreading southward along isopycnals.

A sample of SeaSoar Hydroscat measurements centered near the front at 39° 30’ N (Figure 3) reveals high backscatter to depths of 40 m south of the front, extending to 80 m farther north. Of particular interest is the tongue of elevated backscatter extending southward at depths between 75-125 m, near

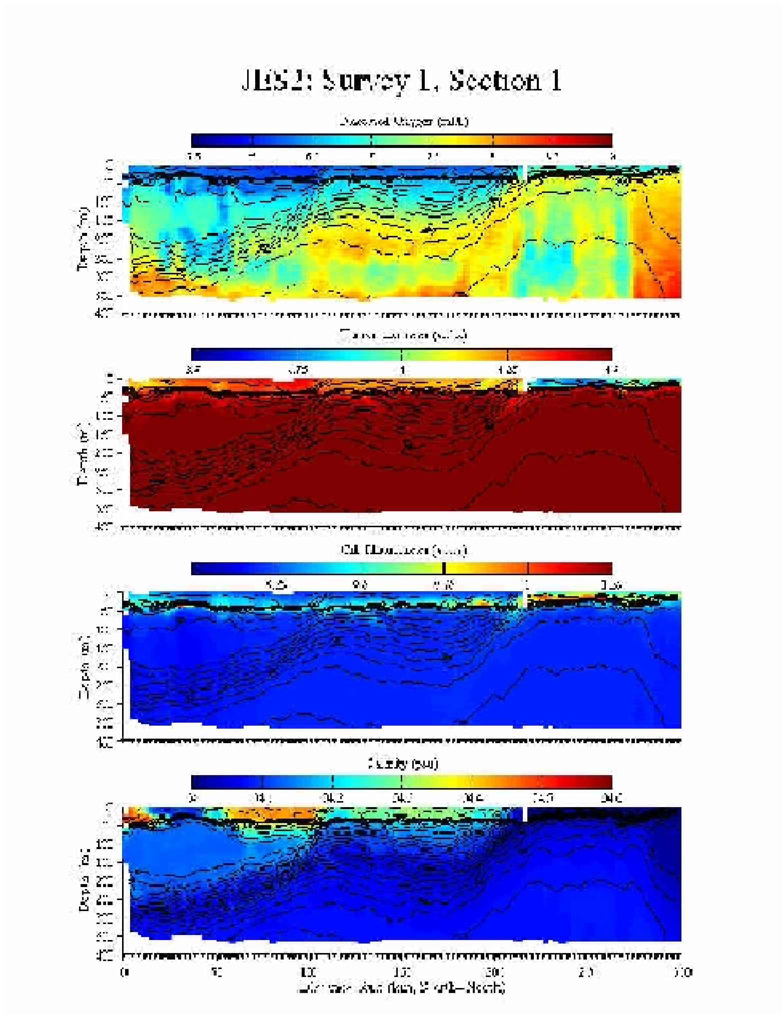

Figure 2. The westernmost section across the subpolar front, from 37° 45' N to 40° 20' N along 134° E. From top to bottom, the panel display (contours/colors): • . /dissolved oxygen, • . /light transmission, • . /chlorophyll fluorescence and temperature/salinity. Note that all calibrations are preliminary and fluorescence and transmission are shown in volts. Specifically, dissolved oxygen measurements are only roughly calibrated, and show clearly bogus values beneath the seasonal pycnocline. SeaSoar oxygen near • . . = 27kg/m^3 and shallower agree roughly with bottle measurements. High values indicate high chlorophyll content or low light transmission.

the 27 kg/m^3 isopycnal. This coincides with the region of elevated dissolved oxygen that traces the frontal interface (Figure 1) and suggests that bio-optical properties (particulate and dissolved material) may trace waters that are subducted at the front and carried southward into the interior.

RELATED PROJECTS

Our efforts are part of an intensive, multi-investigator study of the Japan/East Sea. We intend to collaborate closely, both in the measurement and analysis phases, with other Japan/East Sea projects. In particular, we anticipate cooperation with the following components:

Satellite Characterization of Bio-Optical and Thermal Variability in the Japan/East Sea, B. Arnone, (NRL).

Atmospheric Forcing and its Spatial Variability over the Japan/East Sea, R. Beardsley, A. Rogerson (WHOI) and C. Dorman (SIO).

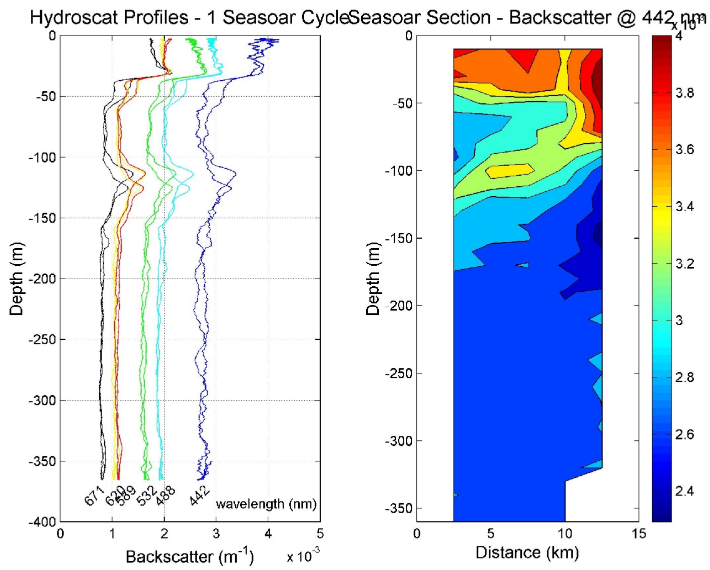

Figure 3. Hydroscat measurements from the same section as displayed in Figure 1.The left panel displays the vertical distribution of backscatter from the 6 Hydroscat channels for a single SeaSoar profile south of the front. The right panel shows a short section (south-north) of backscatter (442 nm) centered near the subpolar front at 39° 30' N. Note the tongue of elevated backscatter extending southward beneath the seasonal pycnocline.

Studies of Physical and Biological Processes in the Japan/East Sea using Coupled Numerical Models, C. Paulson (Purdue University) and L. Kantha (University of Colorado).

Optical Properties as Tracers of Water Mass Structure and Circulation, G. Mitchell, D. Stramski and P. Flatau (SIO).

Glider Surveys of the Japan/East Sea Circulation, C. Eriksen (University of Washington).

Modeling Support for CREAMS II: Oceanic and Atmospheric Mesoscale Circulation and Marine Ecosystem Simulations for the Japan/East Sea, C. Mooers and S. Chen (University of Miami).

Wind Forcing of Currents in the Japan/East Sea, P. Niiler (S.I.O.), D. Lee (Pusan National University) and S. Hahn (National Fisheries Research and Development Institute).

Observations of Upper Ocean Hydrography and Currents in the Japan/East Sea using PALACE Floats, S. Riser (University of Washington).

Hydrographic Measurements in Support of Japan/East Sea Circulation, L. Talley (SIO).

Shallow and Deep Current Variability in the Southwestern Japan/East Sea, R. Watts and M. Wimbush (University of Rhode Island).

IMPACT/APPLICATION

Highly resolved, three-dimensional upper ocean measurements provide a unique picture of the integrated effects of wintertime water mass formation in response to strong atmospheric forcing. Simultaneous measurements of bio-optical properties contrasts conditions on either side of the front and permit us to study the role of dynamics in controlling bio-optical variability. Both at the subpolar front and off the Korean coast, SeaSoar surveys provide bio-optical measurements of unprecedented synopticity and horizontal resolution.

TRANSITIONS

None.

PUBLICATIONS

Lee, C. M., C. E. Dorman, R. W. Gould and B. H. Jones (1999) Perliminary Cruise Report: Hahnaro 5-Dynamics, Biology, Optics and Meteorology of the Subpolar Front in the Japan/East Sea. Technical Memorandum, APL-UW TM 3-99, Applied Physics Laboratory, University of Washington, 65pp.